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Masatomo Tachi and Hirotoshi Iwata

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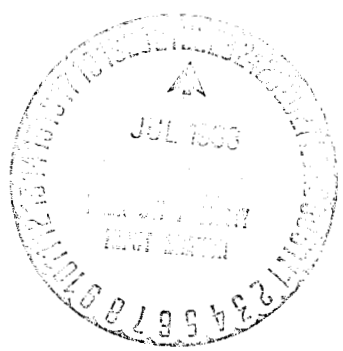

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FINGER TIP SKIN TEMPERATURE IN THE MALE AND FEMALE DURING IMMERSION IN COLD WATER

M Tachi (Member) and H. Iwata (Non-member)
(Department of Public Health, School of Medicine, Gifu Univ.)

ABSTRACT: A comparative study of healthy male and female digital skin temperatures during immersion in cold water was made as a means of isolating the causes for a 5: 1 higher incidence of Raynaud's disease in females than in males. Finger tip skin temperature measurements of the two subject groups were recorded during fifteen minute periods of immersion in water held at temperatures levels between 5°C and 30°C, and the following data was obtained: 1) Skin temperature at each water temperature level; 2) Differences between skin and water temperatures; 3) Ratios of skin temperature/water temperature differentials to body temperature/skin temperature differentials.

It was found that female skin temperatures were lower than those of the male when water temperature was 10°C and above. This also was true of the water temperature -- skin temperature differentials, the latter being minimal in the male at 15°C and in the female at 20°C. The highest ratios of the skin/water temperature differentials to the body/skin temperature differentials appeared in both subject groups at 20°C, the males indicating progressively higher ratios beginning at a minimum value of 5°C and the females indicating a drop from the initial 5°C values to a minimum at 15°C.

The writers infer (a) a higher reactivity to ambient temperatures in the female peripheral circulatory system, (b) reaction at higher ambient temperature levels, and (c) lower peripheral blood flow at low temperatures than in the male, all of these reactions are accompanied by less heat loss in the female subject. The writers suggest that the stimulus of cold water acts to reduce the volume of blood flow distal to the arteriovenous anastomosis, but are unable to attribute this effect to any specific cause.

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Introduction

Raynaud's disease is one of the several diseases in which peripheral vascular constriction is evident. The disease, reputedly, most often involves vascular constriction in the periphery of the upper limbs. Acute pain

*Numbers in the margin indicate pagination in the foreign text.

accompanies the spasmodic constrictions, which last for several minutes to several hours, but gangrene occurs when they continue for an overly long period of time. Raynaud believes that the basic causes of this disease can be traced to abnormal sensitivity to the vasoconstrictive mechanism, while Lewis holds that the determinants are to be sought within the blood vessels themselves, rather than in the nervous system. As it has been confirmed that these symptoms can be attenuated by severing the sympathetic nerves, the part played by the nervous system cannot be denied.

The appearance of Raynaud's disease in five women for every affected male, has led to the belief that the endocrine system plays a part in the onset of this disease. It has also been theorized, on the other hand, that there is no great correlation between the symptoms and menstruation.

Symptoms similar to those of Raynaud's disease have been recorded in recent years among operators of vibrating equipment. These symptoms have been described as dead-finger, white-finger, Raynaud's phenomenon, or Raynaud's syndrome. In Japan, it is called "white disease." Just as it is true with respect to Raynaud's disease, however, little is known about the onset, the diagnosis, or the treatment of the disease.

The writers have previously reported on skin temperature measurements as a means of diagnosing Raynaud's phenomenon in vibrating machine (particularly stone finishing machine) operators [1, 2]. This method involves, particularly, skin temperature measurements during immersion in cold water for fixed periods of time. We infer that Raynaud's phenomenon is extensive when there is an extreme drop in skin temperature.

Since Raynaud's disease appears most often in females, a study was made of the differences in male and female skin temperature during immersion of the subject's fingers in cold water. The tests were made on healthy male and female subjects and the results are reported below.

Test Methods

Skin temperature measurements at the tip of the third finger were made subsequent to the immersion in cold water of all of the fingers of the left hand up to the base of the fingers. A Jintan "Thermo" model "Thermofiner" Type-V, was used. The sensor was attached to the tip of the third finger with adhesive plaster (paper tape). The thermometer scale was read every minute subsequent to immersion in cold water. Water temperatures of 5, 10, 15, 20, 25 and 30°C were used, with the period of immersion being 15 minutes at each temperature level. /194

As Figure 1 shows, the temperature readings for the first five minutes showed considerable individual variation with a sudden initial drop and irregularity in some cases, although all of the individual skin temperatures leveled off at the average value during the last ten minutes of each test.

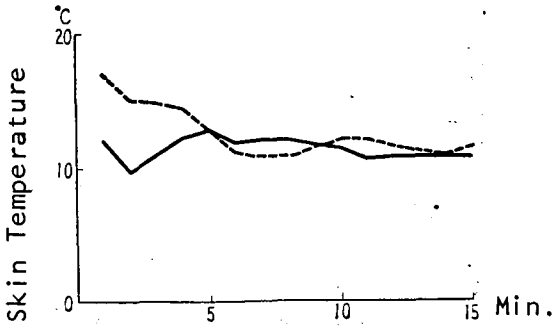

Figure 1. In The Subjects In Which Variation in Skin Temperature Was Observed, The Temperature Dropped Initially During Immersion in Cold Water at 5°C. The Average Skin Temperature Recorded During The Last Ten Minutes of Each Test, However, Was About The Same As That Noted for the Subjects In Which No Initial Temperature Drop Was Experienced.

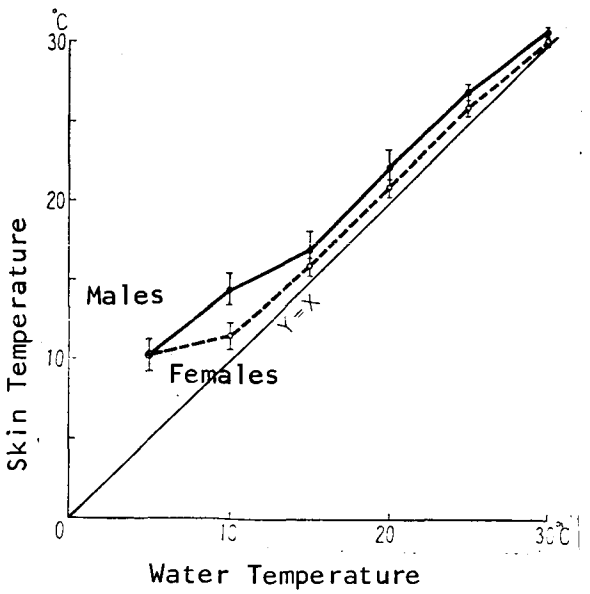

Figure 2. Average Skin Temperature At Given Water Temperature Ranges.

The water temperature was maintained at a constant level with an electric constant temperature tank, ECW 108 W (Tajiri Electric Manufacturing Co. Ltd.). In addition, cold water was circulated at a constant speed around the fingers during immersion.

The subjects were 10 healthy males and six healthy females.) The average readings for the group of ten males and the group of six females were obtained, as was the standard deviation. Observations were made as follows for each water temperature load, (Tw) : (1) The correlation between water temperature and skin temperature (Ts). (2) The Ts and Tw differential (Ts - Tw), and (3) The ratio of the difference between Ts and Tw to the difference between body temperature Tb and Ts. (Ts - Tw) / (Tb - Ts).

Room temperature was maintained at 28 ± 1°C. The tests were made during August and September, 1965. /195

Test Results

Figure 2 gives the skin temperature differences between males and females during finger immersion in cold water at fixed temperature levels between 5 and 30°C. Both the male and female subjects maintained a higher skin temperature than the water temperature at 5°C and there was very little discrepancy between the two subject groups. Skin temperature was higher in the males than it was in the females at water temperatures of 10°C or higher. At water temperatures of 10°C and higher, the female skin temperatures paralleled the line Y = X in the graph and approximated the water temperatures.

Figure 3 gives the Ts-Tw differential for each water temperature load. The value was high for both males and females during immersion in 5°C water.

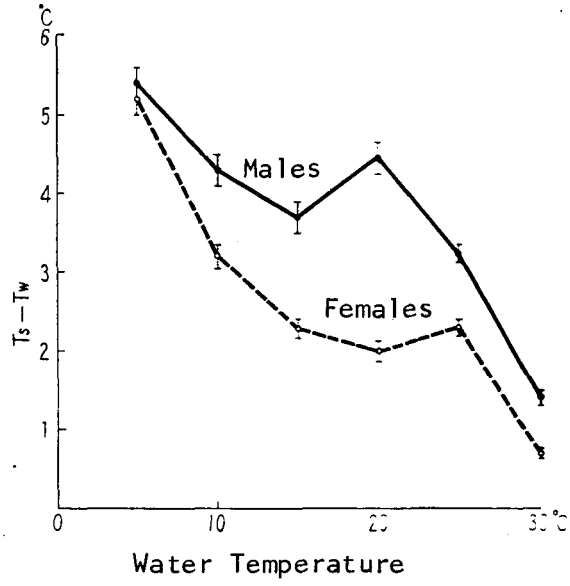

Figure 3. Difference Between Skin Temperature and Water Temperature At Various Water Temperature Levels.

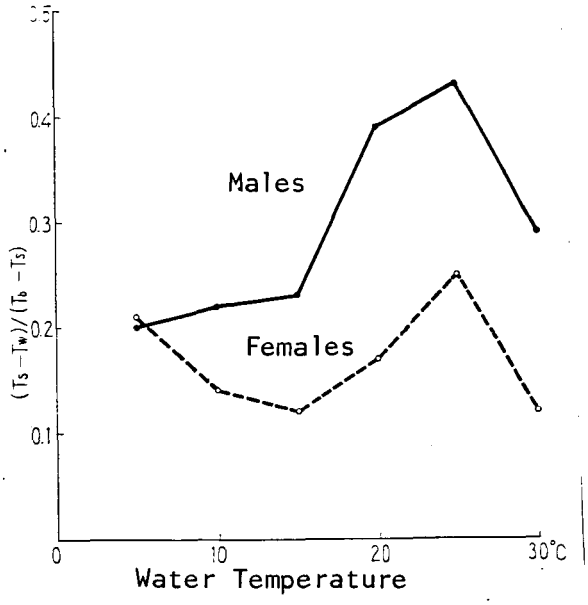

Figure 4. Ratio Of The Skin Temperature -- Water Temperature Differentials To The Body Temperature -- Skin Temperature Differentials At Various Temperature Levels.

The differential dropped to a minimum point in the case of the males at 15°C, where a valley is shown, while the line for the female subjects shows a similar valley at 20°C. The temperature differential virtually disappeared during immersion in water at 30°C, where a value of ± 1°C is shown for both the male and female subjects.

Figure 4 shows the ratio of the differentials (Ts - Tw) / (Tb - Ts). The ratio was 0.2 in the male subjects at water temperatures of 5, 10 and 15°C, thus indicating no difference which could be attributed to water temperature. The ratio shifted to 0.4 during immersion in water at a temperature of 20°C, while the highest value appeared in water at a temperature level of 25°C. In the case of the female subjects, the ratio dropped progressively with immersion at 5, 10 and 15°C, with the minimum value appearing at 15°C. The ratio was 0.17 in 20°C water and reached the maximum value of 0.25 in 25°C water. Over-all, the ratio, (Ts - Tw) / (Tb - Ts) showed higher values in the male subjects than in the female subjects.

Discussion

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The comparison between healthy males and females detailed above was made in an attempt to ascertain the reasons for the more frequent appearance of Raynaud's disease in females.

The data obtained made it apparent that there are major differences in male and female skin temperatures during immersion in cold water and that female skin temperature approximates the water temperature more closely than does that of the

male. Specifically, it is believed these results demonstrate that the peripheral blood vessels of the female react more readily to immersion in cold water than do those of the male. The Ts - Tw differentials are shown in Figure 3 and studies are now in progress [3] to determine whether these differentials are closely interrelated to heat loss. The magnitude of the difference represents the magnitude of the heat loss. With the exception of the results obtained at 5°C, it is believed that there is less heat loss in the female than there is in the male. The differential was minimal in the female at 20°C. In contrast to this, the minimum appeared at 15°C in the male subjects but a high reactivity to water temperature at only 5°C higher than that point was evident in the female leading to the belief that there is a more marked contractibility in the peripheral blood vessels of the female than in the male. It is also inferred that the peripheral blood vessels of the female react at higher air temperature levels than do those of the male.

On the other hand, the ratio (Ts - Tw) / (Tb - Ts) shown in Figure 4 is held to be proportional to the blood flow. [3] On the basis of this thesis, the blood flow in the female is minimal at a water temperature of 15°C, reaching the maximum value at 25°C. In the case of the male, the trend is generally the same, but it is concluded that the volume of flow is higher at all water temperature levels in the male than it is in the female.

Nevertheless, a reduction in both heat loss and blood flow occurs in both the male and the female at water temperatures of 30°C. It is believed /197
that this drop may be attributed to the fact that the intrinsic skin temperature is 30 --- 36°C, prior to immersion in cold water, thus interfering with reactions to water temperature at the 30°C level.

It is not precisely understood what part of the peripheral circulatory system is involved in skin temperature readings, but it is believed that these measurements apply to the blood which flows through the metaarterioles which are distal to the arteriovenous anastomosis. It is believed that in the female digit, the peripheral vascular system works in a compensatory fashion in response to the stimulus of the cold water, reducing the volume of blood beyond the arteriovenous anastomosis, thus lowering the skin temperature.

It is still unclear whether the onset of Raynaud's disease begins with damage to the peripheral blood vessels themselves, is attributable to the action of the peripheral nervous system or finds its origin in the endocrine system. It has been made clear, however, that the skin temperature drops farther in response to a cold water load in females who are not affected by Raynaud's disease than it does in the case of males, and that the response of the female peripheral blood vessels to cold water is marked. On the basis of this point, it appears reasonable that Raynaud's disease is more likely to occur in females than in males.

Conclusions

Since Raynaud's disease appears frequently in females, the following

observations were made to compare skin temperature variations in males and females during exposure to water at various temperature levels between 5 and 30°C. The following results were obtained:

1. There were no major differences between male and female skin temperatures during immersion in water at 5°C. However, female skin temperatures were lower than those of the male during immersion in water at temperatures of 10°C or above.

2. At all water temperature levels, the differences between skin temperature and water temperature were lower in the case of the female than they were in the male. The minimum differential was evident at 15°C in the male, while the minimum appeared at 20°C in the female subject.

3. The ratio between the skin temperature -- water temperature differential and the body temperature -- skin temperature differential was lower in the females than it was in the males. On the basis of the averages for each temperature level, it was found that the highest ratio appeared at 20°C [*SIC*] in both the male and the female subjects. In the case of the female ratios, the graph shows a valley at 15°C, while no such valley appears in the males. The ratio was lowest in the male subjects at 5°C.

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